PROC. ENTOMOL. SOC. WASH.
83(1), 1981, pp. 60–63

2-NONANOL IN THE EXOCRINE SECRETION OF THE NEARCTIC CADDISFLY, *RHYACOPHILA FUSCULA* (WALKER) (RHYACOPHILIDAE: TRICHOPTERA)

R. M. Duffield

Department of Zoology, Howard University, Washington, D.C. 20059.

Abstract.—Abdominal secretions of *Rhyacophila fuscula* (Walker) contain 2-nonanol as the major component. The possible defensive function of the secretion in the biology of the insect and the evolutionary significance of similar abdominal glands in Lepidoptera and Trichoptera are discussed.

In recent years the exocrine chemistry of eusocial insects has been studied extensively in order to determine the controls of their behavioral patterns. The chemistry of a number of economically important non-social insects has also been studied because of the potential application of this information for monitoring and manipulating pest populations (Koehler et al., 1977). Little attention, however, has been directed toward the exocrine chemistry of solitary species. One such taxon is the Trichoptera or caddisflies. They are a small order of insects with about 1300 North American species for which the systematics is relatively well established.

Rhyacophila fuscula (Walker), a common species in the eastern United States, emerges throughout the summer and early autumn. It can be collected in sufficient quantities for chemical analysis by black-lighting. We have observed that this medium-sized caddisfly emits a sweet odor when handled. Herein we report the identification of 2-nonanol from exudates released from a pair of abdominal exocrine glands on the fifth segment. The function of the abdominal gland is discussed as well as its phylogenetic significance.

Materials and Methods

Collection of animals.—Adults of *Rhyacophila fuscula* were collected during September 1979 at Catoctin Mountain Park, Thurmont, Maryland. Adult caddisflies landing on a large white sheet hung behind a black-light were removed and placed in individual glass shell vials. The caddisflies were chilled in an ice chest and transported to the laboratory where they were stored for a maximum of 24 hours prior to extraction.

Exocrine source and collection of secretion.—Female specimens were cleared in KOH and examined both internally and externally for an exocrine glandular apparatus.

Whole body extracts of females were prepared by dipping the specimen in methylene chloride. In addition, the paired exocrine glands on the fifth abdominal segment were dissected from female specimens held under ice water. These excised glands were extracted in methylene chloride for later chemical analysis.

Chemical analyses.—An extract made from 30 whole specimens was analyzed on a computerized Finnigan 3200 gas chromatograph-mass spectrometer (GC-MS) equipped with a 1 m × 1 mm (I.D.) glass column utilizing 3% OV-17 and 10% SP-1000 as stationary phases. The column was programmed at 10°C/min from 60°–200°C (or 300° for OV-17). The major component was identified by comparison of mass spectra and retention times with those of previously published spectra and standard compounds. An extract of eight abdominal glands was analyzed by gas chromatography and the retention time compared to those of standard compounds.

Results and Discussion

Gas chromatograph analyses of both excised glands and whole body extracts of *R. fuscula* showed the presence of one component which constituted over 95% of the observed volatiles. The component has a base peak at m/z 45 with additional peaks at m/z 129, 126, 111, 98, 97, 83, 69, and 55. The molecular ion at m/z 144 was not visible, but the base peak and the M-15 peak at 129 plus the M-18 peak at 126 indicated that this component was 2-nonanol. Comparison with an authentic sample established its structure. The specific stereochemistry of the 2-nonanol is unknown.

2-Nonanol has previously been identified in the head extracts of two species of stingless bees in Mexico, *Trigona mexicana* Guérin and *T. pectoralis* Dalla Torre. 2-Nonanol along with a series of alcohols and ketones functions to release alarm behavior in these bees (Luby et al., 1973). It has also been found in the mandibular glands of bumblebees (Cederberg, 1977). Interestingly, 1-nonanol has been identified in the mandibular gland secretions of the formicine ants, *Lasius niger* (L.) (Bergström and Löfqvist, 1970) and *Oecophylla longinoda* (F.) (Bradshaw et al., 1975) where it functions in signaling alarm.

The chemistry of exocrine secretions of trichopterans has been reported only in one other species, *Pycnopsyche scabripennis* (Rambur) (Limnephilidae). Secretions in this species are dominated by indole along with traces of skatole and cresol (Duffield et al., 1977).

Most caddisflies have paired glandular openings on the fifth abdominal segment (Betten, 1934; Ross, 1956). The presence of an exocrine gland in this segment appears to be a basic caddisfly characteristic which has subsequently been modified in different taxa (Ross, 1956). The structure and position of the gland are variable within the segment. Both males and females of *Pycnopsyche scabripennis* have paired glands 1.8 mm in length opening dorsolaterally on the fifth abdominal sternum. There is a peglike cuticular modification near the opening of the gland (Duffield et al., 1977). A large dorsal exocrine gland has been described in the males of the South American caddisfly *Barypenthus* sp. (Odontoceridae) which opens between the fifth and sixth abdominal terga (Barth 1963a, 1963b). This may represent a fusion of the paired fifth abdominal glands or may represent an entirely different gland. The function of the gland is unknown. A number of other species have what appear to be openings of exocrine glands on other abdominal segments (Flint, personal communication). At present there are no comprehensive studies of the distribution and morphology of abdominal exocrine glands present in Trichoptera.

Based on morphology, it is believed that Trichoptera and Lepidoptera are closely related (Carpenter, 1953; Ross, 1955). This is substantiated by the presence of abdominal exocrine glands on the fifth sternum in both primitive families of Microlepidoptera, Micropterygidae and Eriocranidae (Davis, 1975) and the primitive family of caddisflies, Rhyacophilidae. Thus, the presence of exocrine glands in the fifth segment represents a plesiomorphic character shared by both caddisflies and some primitive Lepidoptera.

The function of these abdominal glands may also be similar in both orders. Kristensen (1972) has suggested they may serve a defensive purpose in the Microlepidoptera. In Trichoptera they may be used to repel small invaders such as ants while the caddisflies rest in the vegetation during daylight hours (Duffield et al., 1977). Since 1-nonanol functions as an alarm releaser/defensive product in *Lasius* and *Oecophylla*, 2-nonanol may function similarly for caddisflies.

The natural product chemistry of the Trichoptera must be regarded as an unexplored field. At this juncture it is impossible to discuss the distribution of 2-nonanol in Trichoptera. Future studies may well demonstrate the usefulness of comparative chemical and morphological data on the fifth abdominal glands in the systematics of Trichoptera. This information may be used both as systematic characters and to test phylogenetic affinities proposed in the literature.

Acknowledgments

We thank D. R. Davis and O. S. Flint, Jr., Department of Entomology, Smithsonian Institution for identifying the specimens and for their helpful suggestions. In addition, we thank Tom McFadden and Jim Voigt (National Park Service), Catoctin Mountain Park, for their cooperation.

Literature Cited

Barth, R. 1963a. Das Duftorgan von *Barypenthus* sp. (Trichoptera: Odontoceridae). Mem. Inst. Oswaldo Cruz, Rio de J. 61: 133–141.

———. 1963b. Ueber eine Besondere Muskelform von *Barypenthus* sp. (Trichoptera). Mem. Inst. Oswaldo Cruz, Rio de J. 61: 143–147.

Bergström, G. and J. Löfqvist. 1970. Chemical basis for odour communication in four species of *Lasius* ants. J. Insect Physiol. 16: 2353–2375.

Betten, C. 1934. The caddisflies or Trichoptera of New York State. N.Y. State Mus. Bull. 292: 1–576.

Bradshaw, J. W. S., R. Baker, and P. E. Howse. 1975. Multicomponent alarm pheromones of the weaver ant. Nature (Lond.) 258: 230–231.

Carpenter, F. M. 1953. The geological history and evolution of insects. Am. Sci. 41: 256–270.

Cederberg, B. 1977. Chemical basis for defense in bumblebees. Proc. Int. Congr. Int. Union Study Social Insects. 8th Centre Agric. Publ., Wageningen, Neth. 1977: 77.

Davis, D. R. 1975. Systematics and zoogeography of the family Neopseustidae with the proposal of a new superfamily (Lepidoptera: Neopseustoidea). Smithson. Contrib. Zool. 210: 1–45.

Duffield, R. M., M. S. Blum, J. B. Wallace, H. A. Lloyd, and F. E. Regnier. 1977. Chemistry of the defensive secretion of the caddisfly *Pycnopsyche scabripennis* (Trichoptera: Limnephilidae). J. Chem. Ecol. 3: 649–656.

Koehler, C. S., J. J. McKelvey, W. L. Roelofs, H. H. Shorey, R. M. Silverstein, and D. L. Wood. 1977. Advancing toward operational behavior-modifying chemicals, pp. 395–400. *In* Shorey, H. H. and J. J. McKelvey, eds., Chemical Control of Insect Behavior, Theory and Application. John Wiley and Sons, New York.

Kristensen, N. P. 1972. Sommerfuglenes stilling i Insektsystemet. Lepidoptera (Copenh.) (n.s.) 2: 61–67.

Luby, J. M., F. E. Regnier, E. T. Clarke, E. C. Weaver, and N. Weaver. 1973. Volatile cephalic substances of the stingless bees, *Trigona mexicana* and *Trigona pectoralis*. J. Insect Physiol. 19: 1111–1127.

Ross, H. H. 1955. The evolution of the insect orders. Entomol. News 66: 197–208.

———. 1956. Evolution and Classification of Mountain Caddisflies. Univ. Ill. Press, Urbana. 231 pp.